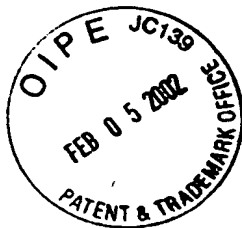




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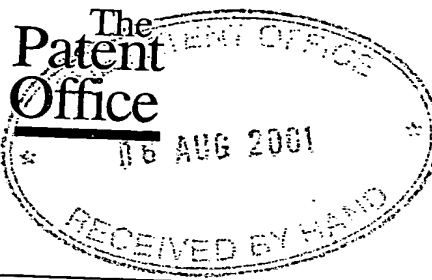
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1. Your reference

85.74444/010

2. Patent application number

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16 AUG 2001

0120028.6

3. Full name, address and postcode of the  
or of each applicant (underline all surnames)

Micromass Limited  
Floats Road  
Wythenshawe  
Manchester M23 9LZ  
United Kingdom  
17AUG01 E653460-1 D00027  
P01/7700 0.00-0120028.6

Patents ADP number (if you know it)

06996102001

If the applicant is a corporate body, give  
country/state of incorporation

UK

4. Title of the invention

Mass spectrometers and methods of mass  
spectrometry

5. Name of your agent (if you have one)

Frank B. Dehn & Co.

"Address for service" in the United Kingdom  
to which all correspondence should be sent  
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179 Queen Victoria Street  
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EC4V 4EL

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166001

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Country	Priority application number (if you know it)	Date of filing (day / month / year)
GB	0029088.2	29/11/00
GB	0109760.9	20/04/01
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Claim(s)	6	✓
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Date 15 August 2001

12. Name and daytime telephone number of person to contact in the United Kingdom

P.M. Jeffrey  
01273 244200

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74444010.352

# MASS SPECTROMETERS AND METHODS OF MASS SPECTROMETRY

5           The present invention relates to mass spectrometers and methods of mass spectrometry.

          Ion guides comprising rf-only multipole rod sets such as quadrupoles, hexapoles and octopoles are well known.

10           An alternative type of ion guide known as an "ion funnel" has recently been proposed by Smith and co-workers at Pacific Northwest National Laboratory. An ion funnel comprises a stack of ring electrodes of constant external diameter but which have progressively  
15 smaller internal apertures. A dc voltage/potential gradient is applied along the length of the ion guide in order to urge ions through the ion funnel which would otherwise act as an ion mirror.

          A variant of the standard ion funnel arrangement is  
20 disclosed in Anal. Chem. 2000, 72, 2247-2255 and comprises an initial drift section comprising ring electrodes having constant internal diameters and a funnel section comprising ring electrodes having uniformly decreasing internal diameters. A dc voltage  
25 gradient is applied across both sections in order to urge ions through the ion funnel.

          Ion funnels have not been successfully employed in commercial mass spectrometers to date.

          One reason for this may be that ion funnels suffer  
30 from a narrow bandpass transmission efficiency i.e. the ion funnel may, for example, only efficiently transmit ions having mass to charge ratios ("m/z") falling within a narrow range e.g.  $100 < m/z < 200$ . Reference is made, for example, to Figs. 5A and 5B of Anal. Chem. 1998, 70,  
35 4111-4119 wherein experimental results are presented comparing observed mass spectra obtained using an ion funnel with that obtained using a conventional ion guide. The experimental results show that both

relatively low  $m/z$  and relatively high  $m/z$  ions fail to be transmitted by the ion funnel. Reference is also made to pages 2249 and 2250 of Anal. Chem 2000, 72, 2247-2255 which similarly recognises that ion funnels  
5 suffer from an undesirably narrow  $m/z$  transmission window.

Another reason may be that ion funnel ion guides require both an rf voltage and a dc voltage gradient to be applied to the ring electrodes. However, the design  
10 and manufacture of a reliable power supply capable of supplying both an rf voltage and a dc voltage gradient which is decoupled from the rf voltage is a non-trivial matter and increases the overall manufacturing cost of the mass spectrometer.

15 It is therefore desired to provide an improved ion guide.

According to a first aspect of the present invention, there is provided a mass spectrometer as claimed in claim 1.

20 The preferred embodiment comprises a plurality of electrodes wherein most if not all of the electrodes have apertures which are substantially the same size. The apertures are preferably circular in shape, and the outer circumference of the electrodes may also be  
25 circular. In one embodiment the electrodes may comprise ring or annular electrodes. However, the outer circumference of the electrodes does not need to be circular and embodiments of the present invention are contemplated wherein the outer profile of the electrodes  
30 may take on other shapes. The preferred embodiment wherein the internal apertures of each of the electrodes are either identical or substantially similar is referred to hereinafter as an "ion tunnel" in contrast to ion funnels which have ring electrodes with internal  
35 apertures which become progressively smaller in size.

One advantage of the preferred embodiment is that the ion guide does not suffer from a narrow or limited mass to charge ratio transmission efficiency which

appears to be inherent with ion funnel arrangements.

Another advantage of the preferred embodiment is that a dc voltage gradient is not and does not need to be applied to the ion guide. The resulting power supply  
5 for the ion guide can therefore be significantly simplified compared with that required for an ion funnel thereby saving costs and increasing reliability.

An additional advantage of the preferred embodiment is that it has been found to exhibit an approximately  
10 75% improvement in ion transmission efficiency compared with a conventional multipole, e.g. hexapole, ion guide. The reasons for this enhanced ion transmission efficiency are not fully understood, but it is thought that the ion tunnel may have a greater acceptance angle  
15 and a greater acceptance area than a comparable multipole rod set ion guide.

The preferred ion guide therefore represents a significant improvement over other known ion guides.

Various types of ion optical devices other than an  
20 ion tunnel ion guide are known including multipole rod sets, Einzel lenses, segmented multipoles, short (solid) quadrupole pre/post filter lenses ("stubbies"), 3D quadrupole ion traps comprising a central doughnut shaped electrode together with two concave end cap  
25 electrodes, and linear (2D) quadrupole ion traps comprising a multipole rod set with entrance and exit ring electrodes. However, such devices are not intended to fall within the scope of the present invention.

According to the preferred embodiment, the input  
30 vacuum chamber is arranged to be maintained at a relatively high pressure i.e. at least a few mbar. According to an embodiment, the input vacuum chamber may be arranged to be maintained at a pressure above a minimum value as specified in claim 1 and less than or  
35 equal to a maximum value such as 20 or 30 mbar.

Embodiments of the present invention are also contemplated, wherein if the AC-only ion guide is considered to have a length L and is maintained in the

input vacuum chamber at a pressure P, then the pressure-length product  $p \times L$  is selected from the group comprising: (i)  $\geq 1$  mbar cm; (ii)  $\geq 2$  mbar cm; (iii)  $\geq 5$  mbar cm; (iv)  $\geq 10$  mbar cm; (v)  $\geq 15$  mbar cm; (vi)  $\geq 20$  mbar cm; (vii)  $\geq 25$  mbar cm; (viii)  $\geq 30$  mbar cm; (ix)  $\geq 40$  mbar cm; (x)  $\geq 50$  mbar cm; (xi)  $\geq 60$  mbar cm; (xii)  $\geq 70$  mbar cm; (xiii)  $\geq 80$  mbar cm; (xiv)  $\geq 90$  mbar cm; (xv)  $\geq 100$  mbar cm; (xvi)  $\geq 110$  mbar cm; (xvii)  $\geq 120$  mbar cm; (xviii)  $\geq 130$  mbar cm; (xix)  $\geq 140$  mbar cm; (xx)  $\geq 150$  mbar cm; (xxi)  $\geq 160$  mbar cm; (xxii)  $\geq 170$  mbar cm; (xxiii)  $\geq 180$  mbar cm; (xxiv)  $\geq 190$  mbar cm; and (xxv)  $\geq 200$  mbar cm.

The electrodes are preferably relatively thin e.g.  $\leq 2$  mm, further preferably  $\leq 1$  mm, further preferably  $0.5 \pm 0.2$  mm, further preferably  $0.7 \pm 0.1$  mm thick. According to a particularly preferred embodiment the electrodes have a thickness within the range 0.5-0.7 mm in contrast to multipole rod sets which are typically  $> 10$  cm long.

Each, or at least a majority of the electrodes forming the AC-only ion guide may comprise either a plate having an aperture therein, or a wire or rod bent to form a closed ring or a nearly closed ring. The outer profile of the electrodes may or may not be circular.

Preferably, alternate electrodes are connected together and to one of the output connections of a single AC generator.

The AC-only ion guide preferably comprises at least 4, 5, 6, 7, 8, 9, 10, 20, 30, 40, 50, 60, 70, 80, 90 or 100 electrodes.

The electrodes forming the AC-only ion guide may have internal diameters or dimensions selected from the group comprising: (i)  $\leq 5.0$  mm; (ii)  $\leq 4.5$  mm; (iii)  $\leq 4.0$  mm; (iv)  $\leq 3.5$  mm; (v)  $\leq 3.0$  mm; (vi)  $\leq 2.5$  mm; (vii)  $3.0 \pm 0.5$  mm; (viii)  $\leq 10.0$  mm; (ix)  $\leq 9.0$  mm; (x)  $\leq 8.0$  mm; (xi)  $\leq 7.0$  mm; (xii)  $\leq 6.0$  mm; (xiii)  $5.0 \pm 0.5$  mm; and (xiv) 4-6 mm.

The length of the AC-only ion guide may be selected from the group comprising: (i)  $\geq 100$  mm; (ii)  $\geq 120$  mm; (iii)  $\geq 150$  mm; (iv)  $130 \pm 10$  mm; (v) 100-150 mm; (vi)  $\leq 160$  mm; (vii)  $\leq 180$  mm; (viii)  $\leq 200$  mm; (ix) 130-150 mm; (x) 120-180 mm; (xi) 120-140 mm; (xii)  $130 \text{ mm} \pm 5, 10, 15, 20, 25 \text{ or } 30$  mm; (xiii) 50-300 mm; (xiv) 150-300 mm; (xv)  $\geq 50$  mm; (xvi) 50-100 mm; (xvii) 60-90 mm; (xviii)  $\geq 75$  mm; (xix) 50-75 mm; and (xx) 75-100 mm.

Preferably, an intermediate vacuum chamber may be disposed between the input vacuum chamber and the analyzer vacuum chamber, the intermediate vacuum chamber comprising an AC-only ion guide for transmitting ions through the intermediate vacuum chamber, the AC-only ion guide arranged in the intermediate vacuum chamber comprising a plurality of electrodes having apertures, the apertures being aligned so that ions travel through them as they are transmitted by the ion guide. At least one further differential pumping apertured electrode is provided through which ions may pass. The further differential pumping apertured electrode is disposed between the vacuum chambers to allow the intermediate vacuum chamber to be maintained at a lower pressure than the input vacuum chamber, and the analyzer vacuum chamber to be maintained at a lower pressure than the intermediate vacuum chamber. An alternating current (AC) generator is connected to an intermediate chamber reference potential for providing AC potentials to the AC-only ion guide in the intermediate vacuum chamber.

Preferably, at least 90%, and preferably 100%, of the apertures of the electrodes forming the AC-only ion guide in said intermediate vacuum chamber are substantially the same size, and at least 90%, and preferably 100%, of the plurality of the electrodes forming the AC-only ion guide in the intermediate vacuum chamber are connected to the AC generator connected to the intermediate chamber reference potential in such a way that at any instant during an AC cycle of the output of the AC generator, adjacent ones of the electrodes



forming the AC-only ion guide arranged in the intermediate vacuum chamber are supplied respectively with approximately equal positive and negative potentials relative to the intermediate chamber reference potential.

Preferably, the AC-only ion guide in the intermediate vacuum chamber comprises at least 4, 5, 6, 7, 8, 9, 10, 20, 30, 40, 50, 60, 70, 80, 90, or 100 electrodes.

Preferably, the intermediate vacuum chamber is arranged to be maintained at a pressure selected from the group comprising: (i)  $10^{-3}$ - $10^{-2}$  mbar; (ii)  $\geq 2 \times 10^{-3}$  mbar; (iii)  $\geq 5 \times 10^{-3}$  mbar; (iv)  $\leq 10^{-2}$  mbar; (v)  $10^{-3}$ - $5 \times 10^{-3}$  mbar; and (vi)  $5 \times 10^{-3}$ - $10^{-2}$  mbar.

Preferably, the electrodes forming the AC-only ion guide in the intermediate vacuum chamber have internal diameters or dimensions selected from the group comprising: (i)  $\leq 5.0$  mm; (ii)  $\leq 4.5$  mm; (iii)  $\leq 4.0$  mm; (iv)  $\leq 3.5$  mm; (v)  $\leq 3.0$  mm; (vi)  $\leq 2.5$  mm; (vii)  $3.0 \pm 0.5$  mm; (viii)  $\leq 10.0$  mm; (ix)  $\leq 9.0$  mm; (x)  $\leq 8.0$  mm; (xi)  $\leq 7.0$  mm; (xii)  $\leq 6.0$  mm; (xiii)  $5.0 \pm 0.5$  mm; and (xiv) 4-6 mm.

In one embodiment the individual electrodes in the AC-only ion guide in the input vacuum chamber and/or the AC-only ion guide in the intermediate vacuum chamber preferably have a substantially circular aperture having a diameter selected from the group comprising: (i) 0.5-1.5 mm; (ii) 1.5-2.5 mm; (iii) 2.5-3.5 mm; (iv) 3.5-4.5 mm; (v) 4.5-5.5 mm; (vi) 5.5-6.5 mm; (vii) 6.5-7.5 mm; (viii) 7.5-8.5 mm; (ix) 8.5-9.5 mm; (x) 9.5-10.5 mm; and (xi)  $< 10$  mm.

Preferably, the length of the ion guide in the intermediate vacuum chamber is selected from the group comprising: (i)  $\geq 100$  mm; (ii)  $\geq 120$  mm; (iii)  $\geq 150$  mm; (iv)  $130 \pm 10$  mm; (v) 100-150 mm; (vi)  $\leq 160$  mm; (vii)  $\leq 180$  mm; (viii)  $\leq 200$  mm; (ix) 130-150 mm; (x) 120-180 mm; (xi) 120-140 mm; (xii)  $130 \text{ mm} \pm 5, 10, 15, 20, 25$  or 30 mm; (xiii) 50-300 mm; (xiv) 150-300 mm; (xv)  $\geq 50$  mm;

(xvi) 50-100 mm; (xvii) 60-90 mm; (xviii)  $\geq$  75 mm; (xix) 50-75 mm; and (xx) 75-100 mm.

Preferably, the ion source is an atmospheric pressure ion source.

5        Preferably, the ion source is a continuous ion source.

      An Electrospray ("ES") ion source or an Atmospheric Pressure Chemical Ionisation ("APCI") ion source is particularly preferred. However, other embodiments are  
10       also contemplated wherein the ion source is either an Inductively Coupled Plasma ("ICP") ion source or a Matrix Assisted Laser Desorption Ionisation ("MALDI") ion source at low vacuum or at atmospheric pressure.

      Preferably, the ion mass analyser is selected from  
15       the group comprising: (i) a time-of-flight mass analyser, preferably an orthogonal time of flight mass analyser; (ii) a quadrupole mass analyser; and (iii) a quadrupole ion trap.

      According to a second aspect of the present  
20       invention, there is provided a method of mass spectrometry as claimed in claim 20.

      Various embodiments of the present invention will now be described, by way of example only, and with reference to the accompanying drawings in which:

25       Fig. 1 shows a preferred ion tunnel arrangement;

      Fig. 2 shows a conventional mass spectrometer with an atmospheric pressure ion source and two rf hexapole ion guides disposed in separate vacuum chambers;

30       Fig. 3 shows an embodiment of the present invention wherein one of the hexapole ion guides has been replaced with an ion tunnel; and

      Fig. 4 shows another embodiment of the present invention wherein both hexapole ion guides have been replaced with ion tunnels.

35       As shown in Fig. 1, a preferred ion tunnel 15 comprises a plurality of electrodes 15a, 15b each having an aperture. In the embodiment shown, the outer profile of the electrodes 15a, 15b is circular. However, the

outer profile of the electrodes 15a,15b does not need to be circular. Although the preferred embodiment may be considered to comprise a plurality of ring or annular electrodes, electrodes having other shapes are also contemplated as falling within the scope of the present invention.

Adjacent electrodes 15a,15b are connected to different phases of an AC power supply. For example, the first, third, fifth etc. ring electrodes 15a may be connected to the 0° phase supply 16a, and the second, fourth, sixth etc. ring electrodes 15b may be connected to the 180° phase supply 16b. In one embodiment the AC power supply may be a RF power supply. However, the present invention is not intended to be limited to RF frequencies. Furthermore, "AC" is intended to mean simply that the waveform alternates and hence embodiments of the present invention are also contemplated wherein non-sinusoidal waveforms including square waves are provided. Ions from an ion source pass through the ion tunnel 15 and are efficiently transmitted by it.

In contrast to ion funnels, the dc reference potential about which the AC signal oscillates is substantially the same for each electrode. Unlike ion traps, blocking dc potentials are not applied to either the entrance or exit of the ion tunnel 15.

Fig. 2 shows a conventional mass spectrometer. An Electrospray ("ES") ion source 1 or an Atmospheric Pressure Chemical Ionisation ("APCI") 1,2 ion source emits ions which enter a vacuum chamber 17 pumped by a rotary or mechanical pump 4 via a sample cone 3 and a portion of the gas and ions passes through a differential pumping aperture 21 preferably maintained at 50-120V into a vacuum chamber 18 housing an rf-only hexapole ion guide 6. Vacuum chamber 18 is pumped by a rotary or mechanical pump 7. Ions are transmitted by the rf-only hexapole ion guide 6 through the vacuum chamber 18 and pass through a differential pumping

aperture 8 into a further vacuum chamber 19 pumped by a turbo-molecular pump 10. This vacuum chamber 19 houses another rf-only hexapole ion guide 9. Ions are transmitted by rf-only hexapole ion guide 9 through vacuum chamber 19 and pass through differential pumping aperture 11 into a yet further vacuum chamber 20 which is pumped by a turbo-molecular pump 14. Vacuum chamber 20 houses a prefilter rod set 12, a quadrupole mass filter/analyser 13 and may include other elements such as a collision cell (not shown), a further quadrupole mass filter/analyser together with an ion detector (not shown) or a time of flight analyser (not shown).

Fig. 3 illustrates an embodiment of the present invention wherein hexapole ion guide 6 has been replaced with an ion tunnel 15 according to the preferred embodiment. The other components of the mass spectrometer are substantially the same as described in relation to Fig. 2 and hence will not be described again. The ion tunnel 15 exhibits an improved transmission efficiency of approximately 75% compared with using hexapole ion guide 6 and the ion tunnel 15 does not suffer from as narrow a  $m/z$  bandpass transmission efficiency as is reported with ion funnels. An rf-voltage is applied to the electrodes and the reference potential of the ion tunnel 15 is preferably maintained at 0-2 V dc above the dc potential of the wall forming the differential pumping aperture 11 which is preferably either at ground (0 V dc) or around 40-240 V dc depending upon the mass analyser used. However, the wall forming differential pumping aperture 11 may, of course, be maintained at other dc potentials.

In another less preferred (unillustrated) embodiment, the hexapole ion guide 9 may be replaced by an ion tunnel 15' with hexapole ion guide 6 being maintained.

Fig. 4 shows a particularly preferred embodiment of the present invention wherein both hexapole ion guides 6, 9 have been replaced with ion tunnels 15, 15'. The ion

tunnels 15,15' are about 13 cm in length and preferably comprise approximately 85 ring electrodes. The ion tunnel 15 in vacuum chamber 18 is preferably maintained at a pressure  $\geq 1$  mbar and is supplied with an rf-  
5 voltage at a frequency  $\sim 1$  MHz, and the ion tunnel 15' in vacuum chamber 19 is preferably maintained at a pressure of  $10^{-3}$ - $10^{-2}$  mbar and is supplied with an rf-voltage at a frequency  $\sim 2$  MHz. Rf frequencies of 800 kHz - 3 MHz could also be used for both ion tunnels  
10 15,15' according to further embodiments of the present invention.

The ion tunnel 15' exhibits an improved transmission efficiency of approximately 25%, and hence the combination of ion tunnels 15,15' exhibit an  
15 improved transmission efficiency of approximately 100% compared with using hexapole ion guide 6 in combination with hexapole ion guide 9.

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Claims

- 5     1.     A mass spectrometer comprising:  
         an ion source for producing ions;  
         an input vacuum chamber comprising at least one AC-  
only ion guide for transmitting said ions, said AC-only  
ion guide comprising a plurality of electrodes having  
10     apertures, said apertures being aligned so that ions  
travel through them as they are transmitted by said ion  
guide;  
         an analyzer vacuum chamber comprising an ion mass  
analyzer disposed to receive ions after they have been  
15     transmitted by said ion guide;  
         at least one differential pumping apertured  
electrode through which ions may pass, said at least one  
differential pumping apertured electrode being disposed  
between said input vacuum chamber and said analyzer  
20     vacuum chamber to permit said analyzer vacuum chamber to  
be maintained at a lower pressure than said input vacuum  
chamber;  
         at least one alternating current (AC) generator  
connected to an input chamber reference potential for  
25     providing AC potentials to said plurality of electrodes;  
         wherein:  
         at least 90%, and preferably 100%, of said  
apertures are substantially the same size;  
         at least 90%, and preferably 100%, of said  
30     plurality of electrodes forming said AC-only ion guide  
are connected to said AC generator in such a way that at  
any instant during an AC cycle of the output of said AC  
generator, adjacent ones of said electrodes are supplied  
respectively with approximately equal positive and  
35     negative potentials relative to said input chamber  
reference potential; and  
         wherein said input vacuum chamber is arranged to be  
maintained at a pressure selected from the group

comprising: (i)  $\geq 0.1$  mbar; (ii)  $\geq 0.5$  mbar; (iii)  $\geq 0.7$  mbar; (iv)  $\geq 1.0$  mbar; (v)  $\geq 1.3$  mbar; (vi)  $\geq 1.5$  mbar; (viii)  $\geq 2.0$  mbar; (ix)  $\geq 2.5$  mbar; (x)  $\geq 3.0$  mbar; (xi)  $\geq 3.5$  mbar; (xii)  $\geq 4.0$  mbar; (xiii)  $\geq 4.5$  mbar; (xiv)  $\geq$   
5 5.0 mbar; (xv)  $\geq 6.0$  mbar; (xvi)  $\geq 7.0$  mbar; (xvii)  $\geq$  8.0 mbar; (xviii)  $\geq 9.0$  mbar; (xix)  $\geq 10.0$  mbar; (xx) 1-5 mbar; (xxi) 1-2 mbar; (xxii) 0.5-1.5 mbar; (xxiii)  $\leq$  20 mbar; and (xxiv)  $\leq 30$  mbar.

10 2. A mass spectrometer as claimed in claim 1, wherein said electrodes comprise a plate having an aperture therein.

15 3. A mass spectrometer as claimed in claim 1, wherein said electrodes comprise a wire or rod bent to form a substantially closed ring.

20 4. A mass spectrometer as claimed in claim 1, 2 or 3, wherein alternate ones of said electrodes are connected to each other and to one of the output connections of a single AC generator.

25 5. A mass spectrometer as claimed in any previous claim, wherein the AC-only ion guide comprises at least 4, 5, 6, 7, 8, 9, 10, 20, 30, 40, 50, 60, 70, 80, 90, or 100 electrodes.

30 6. A mass spectrometer as claimed in any preceding claim, wherein said electrodes have internal diameters or dimensions selected from the group comprising: (i)  $\leq 5.0$  mm; (ii)  $\leq 4.5$  mm; (iii)  $\leq 4.0$  mm; (iv)  $\leq 3.5$  mm; (v)  $\leq 3.0$  mm; (vi)  $\leq 2.5$  mm; (vii)  $3.0 \pm 0.5$  mm; (viii)  $\leq 10.0$  mm; (ix)  $\leq 9.0$  mm; (x)  $\leq 8.0$  mm; (xi)  $\leq 7.0$  mm; (xii)  $\leq 6.0$  mm; (xiii)  $5.0 \pm 0.5$  mm; and (xiv) 4-6 mm.

35 7. A mass spectrometer as claimed in any preceding claim, wherein the length of said AC-only ion guide is selected from the group comprising: (i)  $\geq 100$  mm; (ii)  $\geq$

120 mm; (iii)  $\geq 150$  mm; (iv)  $130 \pm 10$  mm; (v) 100-150 mm; (vi)  $\leq 160$  mm; (vii)  $\leq 180$  mm; (viii)  $\leq 200$  mm; (ix) 130-150 mm; (x) 120-180 mm; (xi) 120-140 mm; (xii)  $130 \pm 5, 10, 15, 20, 25$  or  $30$  mm; (xiii) 50-300 mm; (xiv) 5  
15 150-300 mm; (xv)  $\geq 50$  mm; (xvi) 50-100 mm; (xvii) 60-90 mm; (xviii)  $\geq 75$  mm; (xix) 50-75 mm; (xx) 75-100 mm; (xxi) 150-200 mm; (xxii)  $\geq 200$  mm; and (xxiii) 50-200 mm.

10 8. A mass spectrometer as claimed in any previous claim, further comprising:

an intermediate vacuum chamber disposed between said input vacuum chamber and said analyzer vacuum chamber, said intermediate vacuum chamber comprising an  
15 AC-only ion guide for transmitting ions through said intermediate vacuum chamber, said AC-only ion guide arranged in said intermediate vacuum chamber comprising a plurality of electrodes having apertures, the apertures being aligned so that ions travel through them  
20 as they are transmitted by said ion guide;

at least one further differential pumping apertured electrode through which ions may pass, disposed between said vacuum chambers to allow said intermediate vacuum chamber to be maintained at a lower pressure than said  
25 input vacuum chamber, and said analyzer vacuum chamber to be maintained at a lower pressure than said intermediate vacuum chamber; and

an alternating current (AC) generator connected to an intermediate chamber reference potential for  
30 providing AC potentials to the AC-only ion guide in said intermediate vacuum chamber.

9. A mass spectrometer as claimed in claim 8, wherein:  
at least 90%, and preferably 100%, of the apertures  
35 of the electrodes forming said AC-only ion guide in said intermediate vacuum chamber are substantially the same size; and

at least 90%, and preferably 100%, of said



plurality of the electrodes forming said AC-only ion guide in said intermediate vacuum chamber are connected to the AC generator connected to said intermediate chamber reference potential in such a way that at any instant during an AC cycle of the output of the AC generator, adjacent ones of said electrodes forming said AC-only ion guide arranged in said intermediate vacuum chamber are supplied respectively with approximately equal positive and negative potentials relative to said intermediate chamber reference potential.

10. A mass spectrometer as claimed in claim 8 or 9, wherein the AC-only ion guide in said intermediate vacuum chamber comprises at least 4, 5, 6, 7, 8, 9, 10, 20, 30, 40, 50, 60, 70, 80, 90, or 100 electrodes.

11. A mass spectrometer as claimed in any of claims 8, 9 or 10, wherein said intermediate vacuum chamber is arranged to be maintained at a pressure selected from the group comprising: (i)  $10^{-3}$ - $10^{-2}$  mbar; (ii)  $\geq 2 \times 10^{-3}$  mbar; (iii)  $\geq 5 \times 10^{-3}$  mbar; (iv)  $\leq 10^{-2}$  mbar; (v)  $10^{-3}$ - $5 \times 10^{-3}$  mbar; and (vi)  $5 \times 10^{-3}$ - $10^{-2}$  mbar.

12. A mass spectrometer as claimed in any of claims 8-11, wherein electrodes forming said AC-only ion guide in said intermediate vacuum chamber have internal diameters or dimensions selected from the group comprising: (i)  $\leq 5.0$  mm; (ii)  $\leq 4.5$  mm; (iii)  $\leq 4.0$  mm; (iv)  $\leq 3.5$  mm; (v)  $\leq 3.0$  mm; (vi)  $\leq 2.5$  mm; (vii)  $3.0 \pm 0.5$  mm; (viii)  $\leq 10.0$  mm; (ix)  $\leq 9.0$  mm; (x)  $\leq 8.0$  mm; (xi)  $\leq 7.0$  mm; (xii)  $\leq 6.0$  mm; (xiii)  $5.0 \pm 0.5$  mm; and (xiv) 4-6 mm.

13. A mass spectrometer as claimed in any of claims 8-12, wherein the length of said ion guide in said intermediate vacuum chamber is selected from the group comprising: (i)  $\geq 100$  mm; (ii)  $\geq 120$  mm; (iii)  $\geq 150$  mm; (iv)  $130 \pm 10$  mm; (v) 100-150 mm; (vi)  $\leq 160$  mm; (vii)  $\leq 180$  mm; (viii)  $\leq 200$  mm; (ix) 130-150 mm; (x) 120-180

mm; (xi) 120-140 mm; (xii) 130 mm  $\pm$  5, 10, 15, 20, 25 or  
30 mm; (xiii) 50-300 mm; (xiv) 150-300 mm; (xv)  $\geq$  50 mm;  
(xvi) 50-100 mm; (xvii) 60-90 mm; (xviii)  $\geq$  75 mm; (xix)  
50-75 mm; (xx) 75-100 mm; (xxi) 150-200 mm; (xxii)  $\geq$  200  
5 mm; and (xxiii) 50-200 mm.

14. A mass spectrometer as claimed in any preceding  
claim, wherein said ion source is an atmospheric  
pressure ion source.

10

15. A mass spectrometer as claimed in any preceding  
claim, wherein said ion source is a continuous ion  
source.

15

16. A mass spectrometer as claimed in claim 14 or 15,  
wherein said ion source is an Electrospray ("ES") ion  
source or an Atmospheric Pressure Chemical Ionisation  
("APCI") ion source.

20

17. A mass spectrometer as claimed in claim 14 or 15,  
wherein said ion source is an Inductively Coupled Plasma  
("ICP") ion source.

25

18. A mass spectrometer as claimed in any of claims 1-  
13, wherein said ion source is a Matrix Assisted Laser  
Desorption Ionisation ("MALDI") ion source.

30

19. A mass spectrometer as claimed in any preceding  
claim, wherein said ion mass analyser is selected from  
the group comprising: (i) a time-of-flight mass  
analyser, preferably an orthogonal time of flight mass  
analyser; (ii) a quadrupole mass analyser; and (iii) a  
quadrupole ion trap.

35

20. A method of mass spectrometry, comprising:  
producing ions from an ion source;  
transmitting at least some of said ions through an  
input vacuum chamber comprising at least one AC-only ion

guide for transmitting said ions, said AC-only ion guide comprising a plurality of electrodes having apertures, said apertures being aligned so that ions travel through them as they are transmitted by said ion guide;

5 providing AC potentials to said plurality of electrodes from at least one alternating current (AC) generator connected to an input chamber reference potential;

10 passing said ions to an analyzer vacuum chamber comprising an ion mass analyzer disposed to receive ions after they have been transmitted by said ion guide;

wherein at least one differential pumping apertured electrode is provided through which ions may pass, said at least one differential pumping apertured electrode  
15 being disposed between said input vacuum chamber and said analyzer vacuum chamber to permit said analyzer vacuum chamber to be maintained at a lower pressure than said input vacuum chamber; and

wherein at least 90%, and preferably 100%, of said  
20 apertures are substantially the same size and at least 90%, and preferably 100%, of said plurality of electrodes forming said AC-only ion guide are connected to said AC generator in such a way that at any instant during an AC cycle of the output of said AC generator,  
25 adjacent ones of said electrodes are supplied respectively with approximately equal positive and negative potentials relative to said input chamber reference potential;

said method further comprising the step of:  
30 maintaining said input vacuum chamber at a pressure selected from the group comprising: (i)  $\geq 0.1$  mbar; (ii)  $\geq 0.5$  mbar; (iii)  $\geq 0.7$  mbar; (iv)  $\geq 1.0$  mbar; (v)  $\geq 1.3$  mbar; (vi)  $\geq 1.5$  mbar; (viii)  $\geq 2.0$  mbar; (ix)  $\geq 2.5$  mbar; (x)  $\geq 3.0$  mbar; (xi)  $\geq 3.5$  mbar; (xii)  $\geq 4.0$  mbar;  
35 (xiii)  $\geq 4.5$  mbar; (xiv)  $\geq 5.0$  mbar; (xv)  $\geq 6.0$  mbar; (xvi)  $\geq 7.0$  mbar; (xvii)  $\geq 8.0$  mbar; (xviii)  $\geq 9.0$  mbar; (xix)  $\geq 10.0$  mbar; (xx) 1-5 mbar; (xxi) 1-2 mbar; (xxii) 0.5-1.5 mbar; (xxiii)  $\leq 20$  mbar; and (xxiv)  $\leq 30$  mbar.

ABSTRACT

MASS SPECTROMETERS AND METHODS OF MASS SPECTROMETRY

5           An ion guide 15;15' is disclosed comprising a  
plurality of electrodes 15a,15b each having apertures  
which are preferably circular and substantially the same  
size. The ion guide 15;15' is preferably maintained in  
a vacuum chamber at a relatively high pressure.

10

[Fig. 4]

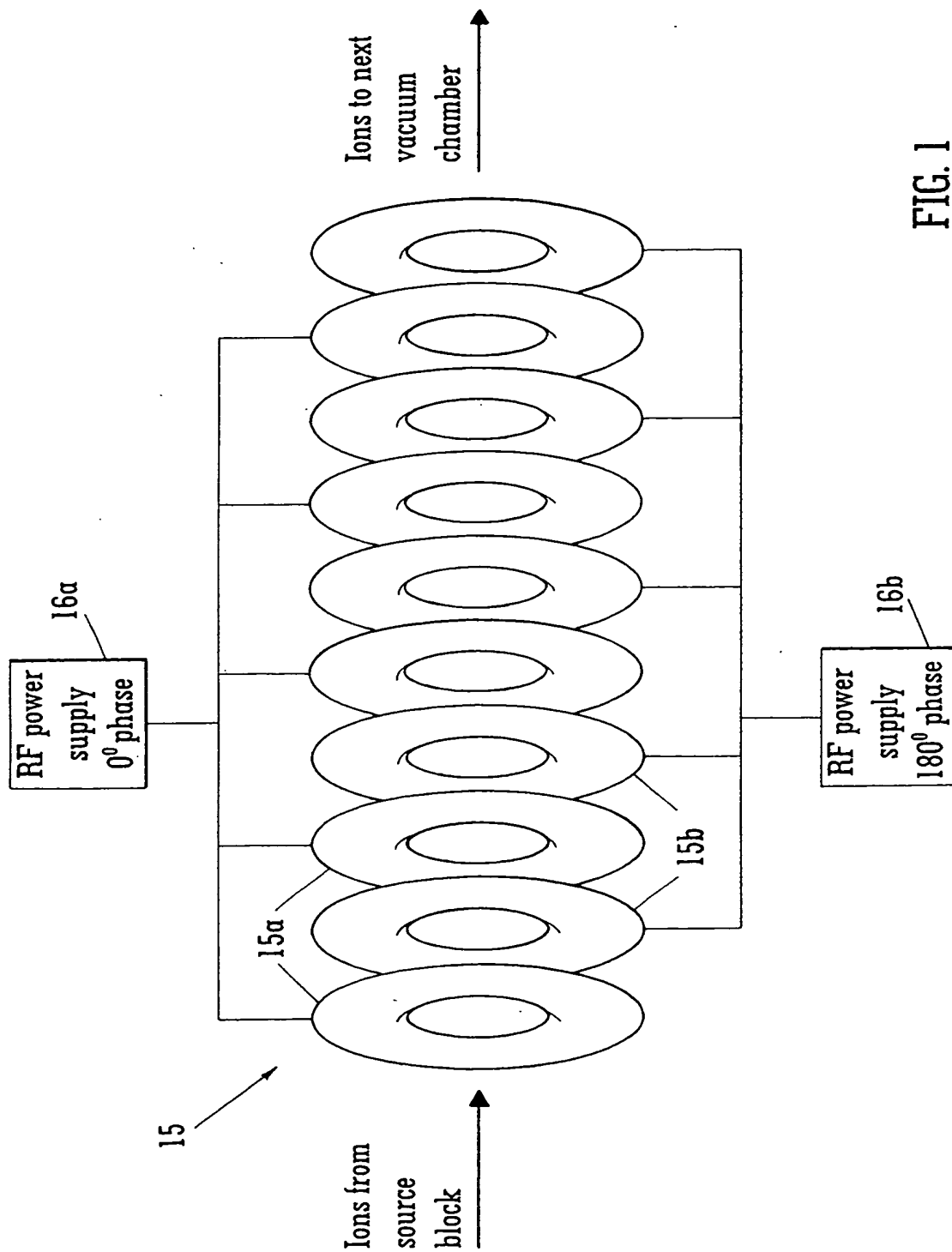
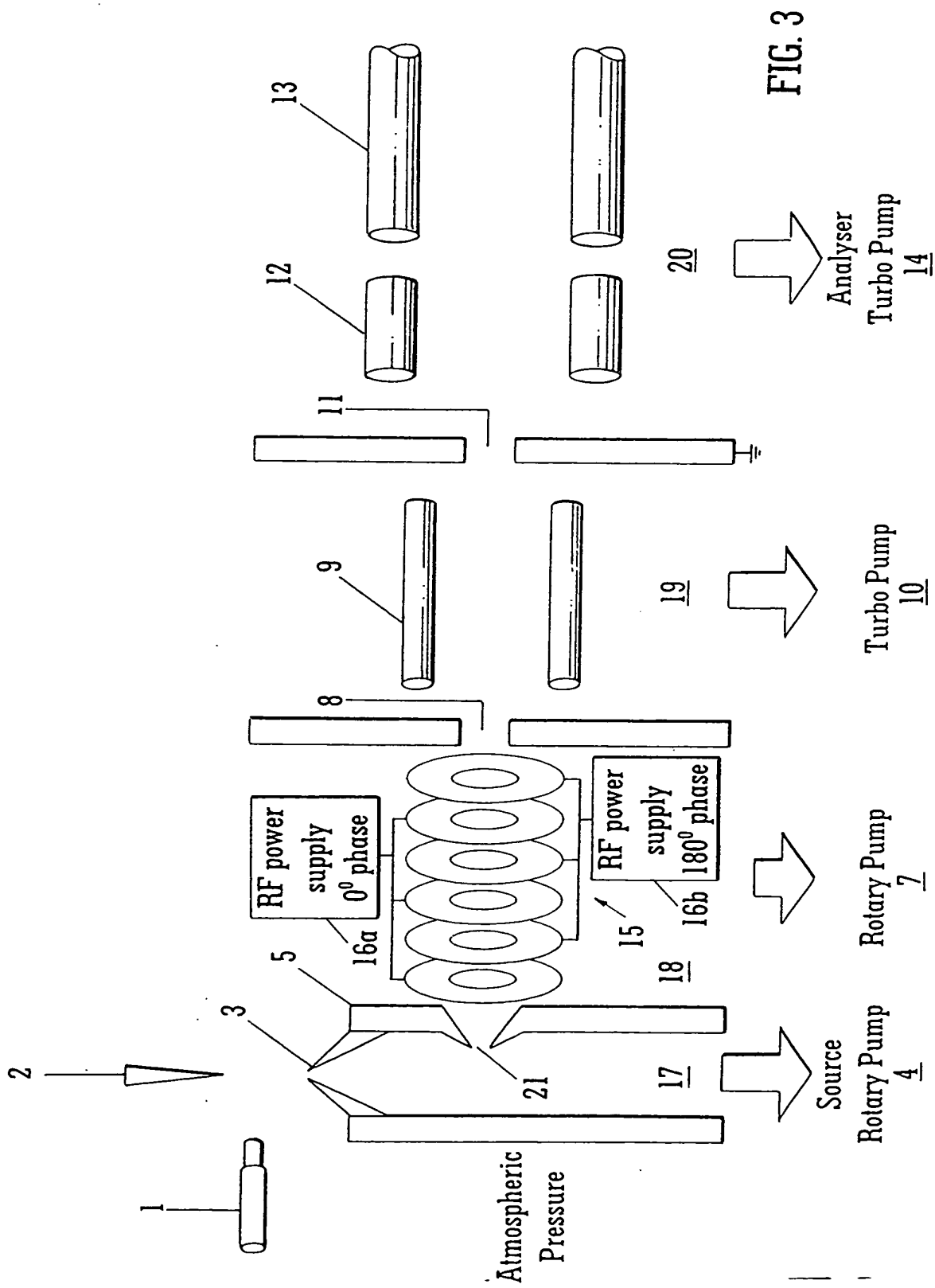


FIG. 1





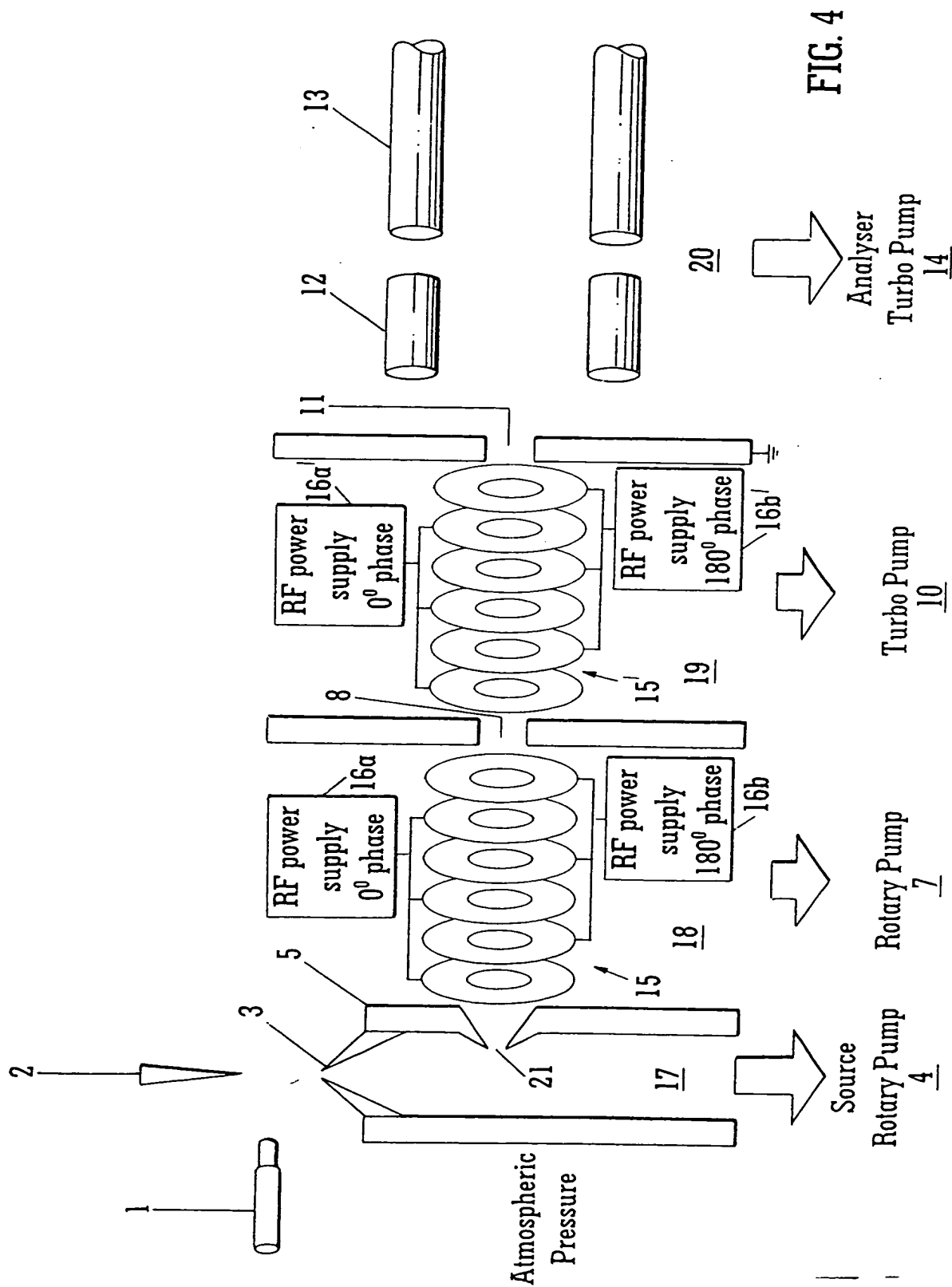


FIG. 4